HANDBOOK

SOIL CONSERVATION SURVEYS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
SOUTHWEST REGION

MAPPING GUIDE

CHAPTER I
SOIL CONSERVATION SURVEY HANDBOOK

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
SOUTHWEST REGION

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FOREWORD

The material presented in this Mapping Guide conforms in principle with the National Guide for Soil Conservation Surveys. However, there are slight differences in the interpretation and arrangement of certain parts. In some instances, minor additions have been made in order to adequately cover conditions that are somewhat peculiar to the Southwest Region.

Supplemental information from various sources has been used as an aid in providing practical and precise descriptions of physical land conditions. Inasmuch as the key for mapping soils was initiated in this region and has been in continuous use since July, 1944, Mr. Hockensmith, Chief, Soil Conservation Surveys Division, has approved continued use of it in the form presented herein.

Since its inception, the Mapping Guide has been continuously improved by the soil scientists in the Southwest Region. Through their cooperative efforts and constructive criticisms, it is now possible to present this material. This Guide has been prepared and arranged primarily by T. B. Hutchings, Assistant Chief, Regional Soil Conservation Surveys Division.

In recent years, the Mapping Guide has contributed and we hope will continue to contribute, to a better understanding and appreciation of the land and its needs.

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SOIL CONSERVATION SERVICE, REGION 6
JUNE 1949 600 M-120-1

GUIDE FOR MAPPING SOIL CONSERVATION SURVEYS

Region 6

Soil conservation surveys are designed to furnish information that is needed to help conservation technicians and farmers plan and apply soil conservation practices. Soil technicians identify land conditions which are important in the use, treatment and management of the land. They show on maps the extent of each significantly different unit.

It is the purpose of this chapter to describe the system used in this region to show these important land features on maps; and define the terms used in this mapping guide insofar as this is practical. This is a regional guide and will be used for making all soil conservation surveys. Survey instructions will be prepared for each district or survey area and will give the actual symbols and precise limits of each for that particular area. The standard symbols as given in the Soil Conservation Survey Handbook - U.S.D.A. Misc. Pub. 352 will be used to show culture, land use, and erosion except as modified herein.

The soil unit, percent slope, and erosion class are the land factors shown in the fraction type symbol. Present land use is shown by a letter within the bounded area. Associated environmental features are also mapped where they are important.

SOIL MAPPING UNITS

Soil mapping units are separated from each other according to mappable differences in the soil properties known to be significant in conservation planning. Some of these can be observed directly, others must be estimated from observable clues. Ordinarily these properties include: Texture of surface soil, permeability of subsoil and substratum, effective depth of the soil, and other factors such as inherent fertility, reaction, available moisture capacity and lime accumulations.

The numerator of the fraction type symbol is the soil unit number. The numerals and/or characters refer to the various layers in the soil.

In the standard unit number there are four digits or letters. The first numeral on the left indicates the surface texture; the second, the permeability of the subsoil; the third, the permeability of the substratum or the nature of the underlying material and the last indicates the depth of the soil.

I. SURFACE SOIL

Texture of the surface soil is a characteristic closely associated with workability. It also influences erodibility, permeability, infiltration, and other soil properties. The 15 or more different textural classes can be grouped into seven or fewer groups for farm planning purposes. These groups are significant in the use and management of the land. Each set of survey instructions will show the textural classes which make up the textural group, or give the percentage limits of 2 micron clay for each group.

The thickness of the surface soil may vary, but generally will be considered as the upper six to twelve inches. The following symbols, terms, and groupings will be used to record and describe surface texture.

Guide No.	Recommended	Possible Alternate	Recommended Textural Classes to be Included
1.	Heavy textured	Very heavy	Clay, silty clay, sandy clay
2.	Moderately heavy textured	Heavy	Silty clay loam, clay loam
3.	Medium textured	Loamy	Sandy clay loam, silt loam, loam, very fine sandy loam
4.	Light textured	Sandy	Fine sandy loam, sandy loam, loamy fine sand
5.	Very light textured	Very sandy	Loamy sand, fine sand, coarse sand
6.	Undifferentiated	- - - -	- - - - - - - - -

The sands included usually contain some silt and clay. By definition, they can contain up to 10% clay or 15% silt. If they contain very little, (usually less than 5% silt and clay) they should be mapped as "P."

The above-recommended textural classes to be included in each textural group are to be used as a guide only. The relative distribution of the soil separates, and variation in the organic matter content or aggregation, or the nature of the clay, may modify the effects of actual 2 micron clay on the workability of the soil. In some districts, it may be necessary to change the textural classes within a group, depending upon the intensity of treatment, type of farming and the resulting planning needs.

When surface soils are less than six inches thick they will be mapped by placing the symbol "∨" over the surface textural digit. When they are more than 12 inches thick, the symbol "∧" will be used.

SOIL KEY FOR MAPPING

Soil Conservation Surveys

REGION 6

Conservation Symbol

$$\frac{\text{1221 - Surface Texture - Subsoil Permeability - Substratum Permeability or Geologic Materials - Depth}}{\text{A-2 \quad Slope \quad ----- \quad Erosion}}$$

Numeral	Texture	Subsoil Permeability	Substratum Permeability	Depth to Inhibiting Layer
1	Heavy	Very slowly permeable	Very slowly permeable	Deep - 36" Plus
2	Moderately heavy	Slowly permeable	Slowly permeable	Moderately deep - 20" - 36"
3	Medium	Moderately permeable	Moderately permeable	Shallow - 12" - 20"
4	Light	Rapidly permeable	Rapidly permeable	-- -- -- --
5	Very light	Very rapidly permeable	Very rapidly permeable	-- -- -- --
6	Undifferentiated	-- -- -- -- --	-- -- -- -- --	-- -- -- --

Geologic or Underlying Materials:

These will be shown only when they are significant in the use and treatment of the land. They will be indicated by placing the appropriate capital letter in the subsoil or substratum position of the symbol: (See exceptions to standard symbols).

A - Acid igneous
B - Basic igneous
C - Shales - poorly consolidated, restrict water movement
E - Shales - consolidated, practically prevent water movement
F - Limestone and lime-cemented hardpans
G - Gypsum beds or strata
H - Gravel and/or cobble mixed with medium textured soil material
I - Gravel and/or cobble mixed with heavy textured soil material
J - Gravel and/or cobble with or without light textured soil material
K - Gravel and/or cobble embedded in zone of high lime accumulation
L - Soft caliche or marl
M - Sandstone - consolidated, practically prevents water movement
N - Sandstone - poorly consolidated, restricts water movement
P - Sand, loose, incoherent sand
R - Arkosic formations
T - Peat
U - Fractured, poorly cemented or thin hardpans

Associated Soil Factors:

Soil profile characteristics not reflected in the soil unit number but which are significant in the use, treatment or productivity of the land, will be indicated by a small case letter, used as a suffix to the soil unit number. Special factor symbols may be used singly or in combination.

a - Inherent fertility significantly below average for soil unit
b - Inherent fertility significantly above average for soil unit
d - Deficient in lime (usually acid soils)
e - Erodibility high due to inherent nature of soil
g - Zone of definite gypsum accumulation in subsoil or substratum
h - Zone of definite lime accumulation in subsoil (Does not limit soil depth)
k - Highly calcareous surface soil
r - Stratified subsoil (indicate slowest permeability in subsoil position)
s - Stratified substratum (indicate slowest permeability in substratum position)
t - Muck soils
$\wedge$ - Horizon or layer thicker than average limits
$\vee$ - Horizon or layer thinner than average limits

Exceptions to Standard Symbol

Soil Materials $= \frac{\text{Geol. Mat.}}{\text{Slope-Eros.}} = \frac{\text{A}}{\text{F-W}}$ and $\frac{\text{Riverwash}}{\text{Slope-Eros.}} = \frac{\text{Rv}}{\text{A-W}}$

Deep soils (Underlain by geol. mat. below 60") $= \frac{\text{Std. Symbol + Geol. Mat.}}{\text{Slope - Erosion}} = \frac{\text{1231A}}{\text{A-1}}$

Very shallow soils (Less than 12") $= \frac{\text{Surf. Tex. + Geol. Mat.}}{\text{Slope - Erosion}} = \frac{\text{1A}}{\text{F-1}}$

Geologic material that has significantly influenced but does not occur in the soil profile $= \frac{\text{Geol. Mat. + Std. Symbol}}{\text{Slope - Erosion}} = \frac{\text{C2221}}{\text{A-1}}$

SPECIAL FACTORS

Cobble and Stones

- O - Cobbly soils-general*
- O_1 - Moderately cobbly
- O_2 - Very cobbly

- X - Stony soils-general*
- X_1 - Moderately stony
- X_2 - Very stony

Salinity

- S - Saline soils - general*
- S_1 - Slightly saline
- S_2 - Moderately saline
- S_3 - Severely saline
- S_4 - Very severely saline
- S_5 - Salinity prevents growth

Alkali

- A - General alkali conditions*
- A_1 - Moderate alkali
- A_2 - Severe alkali
- A_3 - Very severe alkali

Soil Deterioration

Arable Soils - Puddled or dispersed condition shown by overscoring digit representing affected layer (s).

Non-Arable Soils -

- M_1 - Moderate deterioration
- M_2 - Severe deterioration
- M_3 - Very severe deterioration

Watertable within normal root zone

- W - Generally affected by watertable*
- W_0 - Beneficial watertable
- W_1 - Slightly affected by watertable
- W_2 - Moderately affected by watertable
- W_3 - Seriously affected by watertable
- W_4 - Watertable at or very near surface
- W_5 - Permanently wet, swamp areas

Overflow

- f - General overflow conditions*
- f_1 - Occasional overflows
- f_2 - Frequent or destructive overflows
- f_3 - Very frequent damaging overflows

Deficient Moisture

- Z - Inadequate moisture because of position or climate

Position

- T - Lands subject to hazards because of position

Vegetative Obstruction

- V - Vegetation of type and density that clearing is required for cultivation

* Used only on reconnaissance or preliminary surveys where a wide range in conditions is permissible.

When the physical condition of the surface soil is noticeably impaired due to puddling, dispersion or similar causes, the first digit of the unit number is overscored.

Gravelly surface soils - When gravel occurs in sufficient amount to affect the use or treatment of the land, it will be shown by placing the appropriate letter immediately preceding the surface texture numeral.

Gravelly soils* - Those soils containing rock fragments ranging generally from 2 to 64 mm. (.08 to 2.5 inches) in diameter.

0 - Gravelly soils containing 15-50% gravel and rock fragments - .08 to 2.5 inches in diameter.

$\overline{0}$ - Very gravelly soils containing more than 50% gravel and rock fragments. If the matrix is moderately heavy or heavy textured material, the upper limit for gravelly soil may be increased somewhat. The percentages are percent by volume.

II. PERMEABILITY OF THE SUBSOIL AND SUBSTRATUM

The Subsoil in moderately deep and shallow soils is the soil material between the surface soil and the inhibiting layer. In deep soils, the subsoil extends to a depth of about 36 inches. The permeability of this stratum is shown by the second digit of the standard soil unit number. If the subsoil consists of gravel, marl, sand or similar penetrable materials, show the condition by using the appropriate letters to designate these materials.

The Substratum occurs immediately below the subsoil and is described by the third digit or letter in the standard soil unit number. When there is no inhibiting layer within 60 inches of the surface, the substratum consists of effective soil materials and the permeability of the substratum is shown.

An inhibiting layer occurring within 60 inches is shown as the substratum; e.g., 3331 (no inhibiting layer); 33F1 (inhibiting layer between 36-60 inches); 33F2 (inhibiting layer between 20-36 inches); 33F3 (inhibiting layer between 10 and 20 inches).

Permeability is a characteristic or property of a soil and may be defined as its ability to transmit air or water. Permeability can be expressed quantitatively by the measurement of the rate of flow of water through unit cross-section of saturated soil in unit time under specified hydraulic gradient. For comparison of results,

* - Soil Science, 1948. 66:347-363

the conditions of measurement must be known. Permeability of the surface layer of soil affects the rate of infiltration. In a practical way, the rate of intake (permeability) of the first inch or two of soil may determine the maximum rate of infiltration if there are no retarding layers below. The intake rate of the surface soil is extremely variable because of the changes in its physical condition due to use, treatment, or nature of the land. Compaction, dispersion, puddling, the kind of clay, the amount of moisture present, season, and kind and condition of crop or residue markedly affect the rate of infiltration. Because of these variables, we do not show the permeability of the surface soil. We map the texture of the surface soil. If its physical condition is noticeably impaired, the first digit of the unit number is overscored.

Saturated rates are used primarily for comparing the general air and moisture movements of various soils. They may be used in estimating water movement for drainage studies. It is not expected that they be used directly as a basis for calculating irrigation intake rates. The condition of the surface and the amount of moisture present in the soil must be evaluated carefully in trying to make such estimates.

In field mapping, the permeability of the subsoil and substratum will be judged by evaluating the effects that structure, consistence, density, porosity, organic matter and texture have on this soil property. The lack of adequate water-holding capacity is usually of more importance than the rate of water movement in the rapid and very rapidly permeable soils. The permeability will be shown and described as follows:

Guide No.	Description of Rate	Rate - Inches/Hr.
1.	Very slowly permeable	Less than .05
2.	Slowly permeable	0.05 - 0.5
3.	Moderately permeable	0.5 - 2.5
4.	Rapidly permeable	2.5 - 7.5
5.	Very rapidly permeable	More than 7.5

The rates given are tentative. Measurements of rate are made on saturated, undisturbed cores, under gravity with 1 inch variable head. The rates should be given more precise definition if substantiating data are available for a particular area.

III. DEPTH OF SOIL

The depth of soil fixes the volume of material from which plant roots can take water and nutrients. In this guide the soil depth definition is broadened somewhat and refers to the number of inches

of soil material above an inhibiting layer; i.e., the depth to a layer which inhibits root growth or the application of conservation practices. Five depth categories are recognized and are indicated as follows:

Guide No.	Descriptive Terms	Depth Limits
1.	Deep	More than 36"
2.	Moderately deep	20" to 36"
3.	Shallow	10" to 20"
*	Very shallow	Less than 10"
*	Geologic materials	No significant depth

* See Section IV -- Exception to Standard Unit Number

Geologic or Underlying Materials - The following materials are considered to limit the depth of soil because they retard or prevent root growth and development or hinder the application of conservation practices. The degree of impediment varies somewhat between the different materials. It is not intended that these definitions reflect precise geological terminology but rather that they convey an idea of the general nature of the materials. The following definitions and letters will be used to describe the geologic or underlying material.

Igneous rocks - These can be divided into two general classes even though they form a series which varies continuously in composition between the extremes that occur in nature. In one class are those in which silica content is high (usually more than 60%) and the metallic oxides are dominantly Na_2O, K_2O. These materials are generally light colored and are called silicic or acid igneous.

In the other class, the silica is relatively low (usually less than 50-60%) and the metal oxides are dominantly lime (CaO), iron oxides (FeO, Fe_2O_3) and magnesia (MgO). Such materials are usually dark colored and are called basic igneous.

A - Acid igneous rocks: Granite, syenite, rhyolite, etc.

B - Basic igneous rocks: Basalt, gabbro, etc.

Shales - These are compacted clays, muds or silts that possess a finely stratified or laminated structure. They are too fine grained for the component particles to be seen by the unaided eye. As the amount of quartz and grain-size increase, shales grade into sandstones.

C - Shales, poorly consolidated. Restrict water movement.
E - Shales, consolidated, practically prevent water movement (geologic or structureless clays with extremely low percolation rates included).

Limestones - Limestones vary in color from whitish through various shades of yellow, brown and gray to black. Texture is fine grained to aphanitic. Composition is somewhat variable but dominantly calcium or magnesium (dolomitic) carbonates.

Indurated lime-cemented hardpans in a soil affects its use and management similar to limestone materials and will, therefore, be grouped with it.

F - Limestone or lime-cemented hardpans.

Gypsum (anhydrous calcium sulfate - $CaSO_4 \cdot 2H_2O$) - Gypsum is frequently inter-stratified with sedimentary rocks and often occurs in association with salt beds. If the gypsum impedes root penetration, the capital letter will appear in the soil unit number. If it is disseminated throughout the profile in significant quantities and endangers the construction and maintenance of water storage or transporting facilities, the letter "G" will precede the soil unit number.

G - Gypsum beds or strata.

Gravel and/or Cobble - When these materials occur in a soil they generally reduce the moisture-holding capacity in direct proportion to the amount of inert material present. They do not prevent root penetration, but hinder the application of certain conservation practices. Ordinarily, if the subsoils or substrata contain less than 30% by volume of inert material, permeability will be mapped. If they contain more than 30%, the letters will be used. When the inert materials are present to the extent that the soils are relatively ineffective in holding moisture, the letters H and I will be overscored, ($\overline{H}$, $\overline{I}$).

H - Medium textured soil material containing 30% or more by volume of cobble and/or gravel.

I - Heavy textured soil material containing 30% or more by volume of cobble and/or gravel.

J - Light textured soil material (less than 5% silt clay) containing 30% or more of cobble and/or gravel.

K - Gravel and/or cobble imbedded in a zone of lime accumulation (usually exceeds 30% $CaCO_3$). Not indurated, but occasional lenses may be weakly cemented. Water and roots may, but generally do not, penetrate these materials.

Marl - A mixture of soil and lime, known locally as caliche or marl -- usually contains more than 40% calcium carbonate. It is not cemented and is pervious but water and roots generally do not penetrate this material.

L - Soft caliche or marl.

Sandstones - Sandstones are grains of quartz held together by cementing materials which vary widely in composition. This variation in composition of cement accounts in a large measure for the wide range in color. Grain sizes are likewise variable, ranging from those that approach fine silt size up to gravel or cobble size.

M - Sandstone, consolidated.

N - Sandstone, poorly consolidated. Restricts but does not prevent movement of water.

Sand - Loose, incoherent sand usually containing less than 5% silt and clay. It is generally coarser than fine sand. Represented by sand strata in alluvial soils.

P - Sand.

Arkose - A special variety of coarse-grained sandstone in which feldspar grains predominate over quartz. Often considerable mica is present. If firmly cemented, the rock at casual glance resembles granite and will be mapped as "R." Unconsolidated arkose materials will be mapped as "J" (or similar appropriate letter) with the letter "R" preceding the soil unit number.

R - Arkose.

Peat - Material generally composed of more than 50% organic matter which is not well decomposed; plant remains can usually be identified. In addition to regular procedure, symbol may be used as follows: T331 (peat surface); TT31 (peat to depth of 36"); T - (Peat more than three feet in thickness).

T - Peat.

Hardpans - Fractured, poorly-cemented hardpans obstruct tillage but do not prevent penetration of roots and water. Thin hardpans that can be fractured through tillage are included in this group.

U - Fractured, poorly-cemented or thin hardpans.

Any of the above symbols may be modified or given a more precise definition when needed to adequately describe local conditions. All changes from standard definitions, however, must be given in the survey instructions after clearance with state soil scientist and regional office.

IV. EXCEPTIONS TO STANDARD SOIL UNIT NUMBER

Very shallow soils and geologic materials - Special unit numbers are used to show very shallow soils and exposed geologic or other materials. The surface texture number and the letter denoting type of underlying material are all that are used to show very shallow soils as 2A (a very shallow soil with moderately heavy textured surface underlain by acid igneous materials). When no significant amount of soil has been developed, no surface texture is indicated. The exposed geologic materials are shown by the appropriate letter and form the numerator of the symbol.

Geologic materials below 60 inches - In some areas, deeply underlying, geologic materials must be taken into account in land classification because of their effect upon irrigation and drainage. If these materials influence the treatment of the land and occur below 60 inches, they will be shown by placing the letter describing the geologic material following the four-digit unit number. This letter will be shown as a part of the numerator, as 2221E -- a deep soil underlain by consolidated shale materials below 60 inches but close enough to influence drainage and irrigation practices.

Geologic materials influencing soil properties - Some transported soils may be derived largely from a type of geologic material that markedly influences the soil properties. Whenever these properties indicate land needs that are not already shown by the standard unit number, the letter designating the kind of geologic material influencing the soil will be placed in front of the soil unit number. For example, E2221 -- A deep soil whose properties are specifically influenced by the shales from which the soil was derived and special measures are required to improve the permeability of the soil.

Undifferentiated textures and/or permeabilities - Areas that are frequently flooded are often characterized by soils so intermixed that consistent separation is impractical. Textures and permeabilities will not be mapped in such areas. These conditions will be denoted by using the figure "6" alone as the numerator of the symbol. Usually these lands have value for grazing.

Riverwash - Water course or channel area of intermittent streams consisting largely of various sized cobble, gravel and sands. The symbol Rv will be used as the numerator of the fractional or

composite symbol to denote areas of riverwash. Generally such areas have little value for production of grazing or woodland products.

V. ASSOCIATED SOIL FACTORS

The following symbols are to be used to direct attention to certain soil characteristics that are not adequately described by the texture and permeability symbols. These soil characteristics are relatively stable and not easily modified. They point out certain needs or precautions that must be considered in using and treating the land. These characteristics will be shown by placing the appropriate small case letter as a suffix to the soil unit number, as 3221a. This letter will be shown as a part of the numerator. These symbols may be used singly or in combination.

Inherent fertility or nutrient level is a factor in the selection of soil mapping units wherever there are differences that are mappable, and somewhat permanent and significant in land use and management. If two soils have similar characteristics with the exception of inherent fertility, these two kinds of land requiring different treatments will be separated by using the letters as follows:

a - Inherent fertility significantly below average for soil unit.
b - Inherent fertility significantly above average for soil unit.

Lime - Many soils may not contain enough lime to effervesce with dilute acid but unless the pH is below 6.5 - 6.0, they usually have an adequate supply of available calcium. If the pH of the soil is below 6.5, exchangeable calcium determinations should be made. Ordinarily, this symbol will be used to indicate acid soils that need lime.

d - Soils lacking lime.

Highly erodible soils - These will be distinguished from soils that are similar otherwise by using the letter -

e - High erodibility due to inherent nature of soil.

Gypsum - A definite zone of gypsum accumulation which does not significantly hinder root development but which does endanger water storage or irrigation structures, will be shown with the letter -

g - Zone of definite gypsum accumulation in the subsoil or substratum.

<u>A zone of high lime content in the subsoil</u> - This is important to show the need for additional fertilizers and organic matter when limy materials may be exposed in land leveling operations. The actual minimum percentage of lime which interferes with normal plant nutrition is not known precisely. On the basis of the best information available, limits should be established for each area. These limits may vary with different soils because they are, no doubt, influenced by the organic matter content, the permeability, and the mechanical composition of the soil as well as the nature of the parent material. In some instances, the limits may be as low as 2-5%, but ordinarily may be expected to be at least 15 or 20%. When the amount exceeds 40-50%, the conditions can be described more accurately by mapping as caliche or marl.

h - Zone of definite lime accumulation in the subsoil.

<u>Lime in surface</u> - When the lime content of the surface soil approaches the condition described by "h" in the subsoil and is a distinctive feature in determining land needs, this condition will be shown with the letter -

k - Highly calcareous surface soil.

<u>Stratification</u> - In mapping, we are interested in the permeability of each horizon within the effective depth of the soil. However, some soils are so stratified that it is impractical to map the permeability of each layer. The least permeable layer determines the rate of water movement vertically. Therefore, the number denoting the horizon with the lowest permeability will be placed in the subsoil and/or the substratum position and "r" and/or "s" will follow the unit number. In some instances, it may be necessary to use both symbols, but caution is urged against their over-use. They should always supply additional required information to assist in the interpretation of land needs. The relative position and thickness of the layers must be considered carefully. For example, it may not be important to show stratification of "1" with "2" permeabilities or "4" with "5." But it would be very important to show a soil with "1" permeability stratified with materials of "4" permeability. If needed, additional important details about the stratification may be given in the farm write-up.

r - Stratified subsoil.

s - Stratified substratum.

<u>Muck</u> - Soils containing 20% to 50% well-decomposed organic matter will be classed as muck soils and denoted by the symbol -

t - Muck soil.

Relative thickness - When the relative thickness of the different layers or horizons of a soil profile are important in separating soils for classification or treatment recommendations, the caret (or inverted caret) will be used over the number or symbol designating a given layer. In stratified, alluvial soils, these symbols can be used to provide information, to supplement that given by the symbols, "r" or "s." The survey instructions will set forth the depth limits for these symbols.

$\wedge$ - Horizon or layer thicker than average limits.

$\vee$ - Horizon or layer thinner than average limits.

SLOPE

Steepness of slope is a very important land property because it affects the amount and rate of erosion, the application of irrigation water, the use of machinery, and the general management and treatment of the land.

The range of slope as related to treatment needs of the land will vary with different soils. Certain soils can be used for growing row crops on relatively steep slopes while other soils on the same gradient require close growing crops or pasture cover. The limits for slope groups are based on the best information available. The actual limits for each slope group as related to different soils will be listed in the survey instructions. In areas where there is insufficient data to establish slope group limits, it may be desirable to map actual percent of slope up to 6%. Above this percent, limitations are such that regular slope groups may be mapped.

Uneven or irregular slopes will be recognized and mapped when such conditions affect the capability or treatment of the land. The need for showing uneven slopes may vary according to the type of irrigation followed. On border irrigation differences in elevation of .3 foot within 100 feet cause water loss by deep percolation. These small variations in elevation are not measurable with an Abney level but when considered important to land treatment, they will need to be determined by observations.

Slightly uneven or gently undulating slopes will be shown with a sub-numeral 1, as A_1.

Very uneven or markedly undulating slopes will be shown with a sub-numeral 2, as A_2.

Areas that have been bench terraced may be shown by a sub-numeral 3, as B_3. The slope group letter will represent the overall gradient or slope prior to bench leveling.

EROSION

In farm planning conservation surveys, erosion will be mapped in accordance with the limits and general definitions given in the Conservation Surveys Handbook, U.S.D.A. Miscellaneous Publication 352. The relative damage to the land from erosion and its influence upon land use and treatment will be determined by considering the effect of the erosion upon the amount and nature of the remaining soil and its potential as related to its environment. For example, severe erosion on a moderately deep soil may damage the soil significantly, but the same amount of removal on a deep soil may have little effect upon the soil's potential. In some areas, erosion results in a deterioration of the soil which may be largely overcome under proper management and favorable climatic conditions. In these areas, erosion damage will need to be evaluated carefully in determining the capability of the land.

When past erosion effects become less important due to partial stabilization, the interpretation of the condition may be made clearer by mapping this stabilization.

Rather than group erosion symbols that are given in the Handbook (Miscellaneous Publication 352), the following standard symbols will be used. They may be used in combination, but select only those needed to show pertinent conditions. If wind and water erosion symbols are used together, they must be of equal rank and the one denoting major cause placed first. The relative percentage removals given in the Handbook may be used as a guide.

0 - No apparent erosion.
1 - Slight water erosion.
2 - Moderate water erosion, including occasional shallow gullies.
3 - Severe water erosion, including frequent shallow gullies.
6 - Slips, landslides, etc.
7V - Occasional deep gullies.
8V - Frequent deep gullies.
9V - Very frequent deep gullies. Gullies of such size or intricate association that the land is not suited for use under present condition. 9V will be used alone.
+ - Recent deposition.
$\triangle$ - Detrimental deposition.

P - Slight wind erosion.
R - Moderate wind erosion, including accumulation less than 12 inches high.
S - Severe wind erosion.
L - Moderate wind accumulations 12-35 inches high.
M - Severe wind accumulations 36-72 inches high.
N - Dunes, 72 inches or more high.

W - Geologic erosion.
θ - Undifferentiated erosion (townsites, etc.).

Depth of recent deposits may be shown by using numerals in conjunction with the symbol +.

Because information is needed in estimating soil losses and conservation treatments, areas affected by deep gullies will always have the gully symbol in the composite symbol. The average depth and width of deep gullies should be shown, and gully length estimated to the nearest tenth of a mile. This will make it possible to tabulate factual data showing the extent and severity of gully erosion. Following is an example of a symbol showing how the method will be used:

$$\frac{3331}{A - 27V\ 6/4 - .3} \qquad \text{or} \qquad \frac{3331}{A - 27V\ 6/4 - .3}$$

The erosion symbol indicates moderate water erosion damage, occasional deep gullies approximately 6 feet wide and 4 feet deep, gully length about three-tenths of a mile within the delineation.

The soil scientist will determine when gullies should be designated as deep gullies. It will depend on relative dimensions but ordinarily, gullies more than $1\frac{1}{2}$ to 2 feet deep will fall in that category. Estimate width and depth to the nearest foot. The dimensions given should be representative of the condition and not just averages of the extremes. Deep gullies will be shown by a wavy line in red and when more convenient, the gully dimensions may be placed alongside the gully, as 6/4 - .3.

PRESENT LAND USE

Present land use (or cover in the case of land not used for crops) is needed for farm conservation planning and other purposes.

Different land uses can be separated from each other by a dashed line if not already separated by a conservation boundary or cultural symbols such as roads, ditches, fences, etc. A land use symbol is required every time such symbols cross areas delineated within a standard conservation survey boundary. Cultural symbols designating

land use boundaries should be established in survey instructions.

The following symbols and definitions will be used. It is not intended that all detailed breakdowns be used on all surveys. The survey instructions will designate the different land uses to be mapped.

Cropland - This includes all land planted to crops and, in addition, fallow land, orchards, and land seeded down several years to alfalfa, grass or other forage crops grown for hay.

Irrigated:	L	- Cropland (general)
	L_o	- Orchards and vineyards
	L_1	- Pasture
	L_2	- Alfalfa
	L_3	- Row crops
	L_4	- Small grains
Dry farm:	$1L$	- Cropland (general)
	$1L_o$	- Orchards and vineyards
	$1L_1$	- Land seeded to grass
	$1L_2$	- Alfalfa
	$1L_3$	- Row crops
	$1L_4$	- Small grains

Pasture or Range Lands - These include grazing land or range other than pastured woodland. The letter "P" will designate this use. The vegetative types will be shown as a sub-numeral in accordance with the following standard type designations. When more than one type occurs in a given area, the two most important will be shown with the dominant or aspect type listed first, as P_{1-4}.

When trees are consequential in the determination of vegetative type but the intensity is less than 40% and is not adequate to map as woodland, map as pasture but show trees as the main type and the grasses and weeds secondarily, as P_{9-1}.

1. Grassland - Grassland other than meadow. Perennial grasses predominate and determine the aspect although weeds and browse may be present. Examples of type are: Grama-buffalo grass, bunch grass, wheat grass-sedge, alpine grassland, bluestem.

2. Meadow - Areas where sedges, rushes, and moisture-enduring grasses predominate.

3. Perennial forbs (weeds other than desert weeds) - All untimbered areas where perennial weeds predominate over other classes of vegetation. There is very little true weed type,

as a weed cover is usually temporary in character and is soon replaced by a more permanent vegetation if the disturbing factor is removed. If there is no great predominance of the weeds over the grass or brush vegetation and if it is possible to judge that the weed predominance is due to some unnatural factor, the weeds should be disregarded in designating the type and the more stable vegetation should be used as an index.

4. Sagebrush - All untimbered lands where sagebrush predominates. The sagebrush lands usually differ in range values and in season of grazing from the areas that are classified as browse.

5. Browse-shrub - All untimbered lands where browse, except sagebrush or its sub-types, gives the main aspect to the type or is the predominant vegetation. It usually occupies the transition zone of the lower mountain slopes, foothills, and plateau areas. Examples of sub-types are mountain-mahogany, bitterbrush, willows, Ceanothus-manzanita, and California chaparral.

11. Creosote - Areas where creosotebush constitutes the predominant vegetation.

12. Mesquite - Areas where various species of the mesquite give the characteristic aspect or constitute the predominant vegetation.

13. Saltbush - Areas where the various salt desert shrubs of the Atriplex family form the predominant vegetation or give the characteristic aspect.

14. Greasewood - Areas where greasewood (sarcobatus) is the predominant vegetation or gives the characteristic aspect. It is relatively tolerant of salinity and alkali.

15. Winterfat - Areas where winterfat (Eurotia) gives a characteristic aspect or constitutes the predominant vegetation. Though commonly associated with other semi-desert shrubs, the occurrence of this plant in Utah as a type character is of sufficient extent to justify a separate type.

16. Desert shrub - A general type that includes areas where other desert shrubs aside from those separated into individual types constitute the predominant vegetation or gives the characteristic aspect. This type includes several genera that are quite distinctive in

type habit, such as blackbrush (coleogyne), coffeeberry (Simmondsia), catclaw (Acacia, Mimosa), gray molly (Kochia), hopsage (Gravia spinosa), spiny horsebrush (Tetradymia spinosa), and little rabbitbrush (Chrysothamnus stenophyllus), but pure types of each are so limited in extent as not to justify a separate type.

17. Half shrub - Areas where half shrubs constitute the dominant vegetation or give the characteristic aspect. Half shrubs are semi-woody perennials of low stature such as Aplopappus, Gutierrezia, Artemisia frigida, and Eriogonum wrightii. They commonly consist of a woody caudex from which herbaceous stems are produced that die back annually.

18. Annuals (weeds or grasses) - Areas in which weeds or annual grasses constitute the dominant vegetation. Both transitory stages and semi-permanent conditions should be included; as for example: Russian-thistle, downy chess (Bromus tectorum), and desert weeds.

19. Tamarisk - Areas where the shrub type of Tamarisk (Tamarix gallica) predominate. It is frequently called salt cedar because it occurs in saline areas having a high watertable. It has a low palatability, but does have some value as winter forage. Athel (Tamarix aphylla), the erect growing tree of this species and found principally in southern Arizona and southern New Mexico, should be grouped with the broadleaf trees (Forage type 10).

20. Tules - Permanently wet areas that are dominated by tules (typha latifolia) that have little or no forage value.

<u>Woodland</u> - Woodland includes land with 40% of the ground covered by the spread of woodland or forest species and will be shown by the letter "F." If the woodland is grazed, the letter will be overscored. The type of trees will be shown by a sub-numeral according to the types listed below.

6. Conifer - All land in coniferous timber supporting grasses, weeds, or browse, either singly or in combination.

9. Pinon-juniper - Pinon, juniper, pinon-juniper, and digger pine. The forage understory may vary from a pure stand of grasses, weeds, or browse to a combination of any two or all. These variations can best be shown by sub-type designations.

10. Broadleaf trees - All land in deciduous timber. The combination of grasses, weeds, and browse, and the proportion of individual species will vary as in other types.

Idle, Abandoned and Waste Lands - This includes land not being used for the production of useful, harvestable vegetation. Land in fallow is not considered as idle land.

Irrigated: X - Idle or abandoned cropland formerly irrigated, with little or no vegetation.

Dry farm: IX - Idle or abandoned dry cropland, with little or no vegetation.

Wasteland: X_8 - Waste or barren land; includes those areas on which there is naturally no vegetation, or virtually none, such as saline flats, active sand dunes, lava flows, shale and rock outcrops.

If further breakdown is needed, use vegetative type symbols as sub-numerals.

Miscellaneous Lands

H - Urban areas, large farmyards, golf courses, and areas not otherwise classified.

If further breakdown is needed, use vegetative type symbols as sub-numerals.

SPECIAL FACTORS

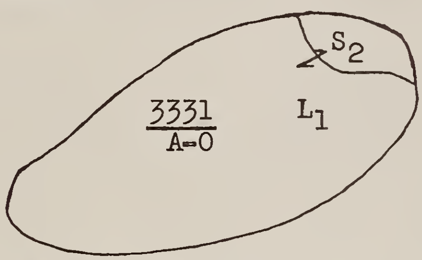
Information on some factors other than soil, slope and erosion is necessary to plan the best use and treatment of certain lands. Such factors as cobble and stone, salinity, alkali, watertable within root zone, susceptibility to flooding, deficient moisture and climatic hazards, soil deterioration, position of the land, and vegetative obstructions all influence somewhat, the treatment of these lands. Ordinarily, most of the conditions described by these factors may be modified or corrected by land conditioning treatments and may be considered temporary limitations. They are basic in determining present condition class, but exert much less influence on the potential or capability of the land.

Lands influenced by these conditions will be delineated using a standard conservation boundary -- a solid black line. In addition

to soil, slope, erosion, and land use symbols, they will contain a special factor symbol. All letters designating special factor conditions will be in red and placed to the right of the fraction-type symbol. When there are more than one, the letters will be placed in the same order as the conditions are discussed herein.

When a small area (less than two acres on 8 inch/mile map) differs only in a special factor condition, show it by bounding the area with a solid black line, place the appropriate special factor symbol in it and connect with a "type tie" to the area with the same soil, slope, and erosion conditions. The "type tie" should not cross more than one conservation type line.

Example:



When a composite symbol cannot be placed within the boundaries of an area, the symbols should be placed immediately adjacent and at approximately a 45-degree angle. Special factor symbols should be placed in the delineated area, if possible; if not, carefully place it following, and in line with, the 45-degree angle composite symbol.

It is not expected that additional separations will be made on the map to show the difference between each special factor intensity. Rather, that the appropriate letter be selected which is most representative of the conditions within the area delineated.

I. COBBLY AND STONY SURFACE SOILS

Cobbly soils - Those soils containing cobble and gravel ranging generally from 64 to 256 mm. (2.5 to 10 inches) in diameter will be shown as cobbly soils by using the following symbols and limits:

- ⊗ - Denotes cobbly conditions in general and will be used only on those surveys where separation into various degrees is not required as in preliminary surveys.
- $⊗_1$ - Moderately cobbly soils: Containing 5% to 40% cobble and gravel.
- $⊗_2$ - Very cobbly soils: Containing more than 40% cobble and gravel.

As the size of the cobble increases, the percent needed to give an equivalent effect decreases.

Stony soils - Those soils containing rock or rock fragments larger than 10 inches in diameter will be shown as stony soils, using the following symbols:

- X - Denotes stony conditions in general and will be used only on those surveys where separation into degrees of stoniness is not required.
- X_1 - Moderately stony soils.
- X_2 - Very stony soils.

The cobble and stone symbols may be overscored to indicate that it is extremely difficult to improve such land by removal of the cobble or stone. Scattered stones, cobble, and gravel will be shown by using the standard symbols, Misc. Pub. 352.

II. SALINE SOILS*

A saline soil is one which contains sufficient soluble salt to impair its productivity. The salt content of soils at which plant growth is affected depends upon: (1) The moisture characteristics of the soil (related to texture); (2) The distribution of salt in the soil profile; (3) Composition of the salts; (4) The species of plant; and (5) The climatic environment. The evaluation of saline conditions is complicated further by seasonal fluctuation or changes due to irrigation or tillage practices. The range in salt concentration within a mappable area will also need to be considered. Because of these inter-related variables, it is difficult to set limits of concentration causing a definite degree of impairment. As data about these variables are accumulated, limits for each degree of salinity should be established for the area and inserted into the survey instructions.

In saline soils, the conductivity of the saturation extract is greater than four millimhos/cm. and the exchangeable-sodium percentage is less than 15. Ordinarily, the pH is less than 8.5 in a 1:5 soil-water suspension. The effect on plants is considered to be osmotic in nature. Concentrations of salt in the soil solution exert osmotic pressures which vary with the concentration and kind of salt. The moisture stress of plants in saline soils is probably due to the sum of the soil moisture tension and the osmotic pressure of the salts.

The following separations are suggested:

- S - Denotes saline (salty) conditions in general -- use only on preliminary or reconnaissance surveys where

* See "Diagnosis and Improvement of Saline and Alkali Soils," U.S. Regional Salinity Laboratory Publication, July, 1947.

wide range in conditions is permissible and separation into sub-divisions is not required.

S_1 - Slightly saline. Crop yields are slightly affected and the range in kind of crops slightly limited. Salt sensitive crops will not do well in the rotation.

S_2 - Moderately saline. Crop yields are moderately affected or the range in the kind of crops moderately limited. Under present conditions, the land can be used for crops in rotation if salt-tolerant crop species are selected.

S_3 - Severely saline. Crop yields are severely affected or the range in kind of crops is severely limited. Under present conditions, the lands are best suited for the production of salt-tolerant forage species.

S_4 - Very severely saline. Land in present condition suitable only for the production of salt-tolerant native forage species.

S_5 - Salinity prevents growth of vegetation.

III. ALKALI SOILS

These soils are characterized by: (1) An exchangeable-sodium percentage greater than 15; (2) Conductivity of the saturation extract is less than four millimhos/cm. and, (3) The pH is generally above 8.5 in 1:5 soil-water suspension. As the percentage of exchangeable sodium increases, the soil tends to disperse more and the pH increases. They are referred to locally as "slick," "chico," or "black alkali" soils. Under certain conditions, these soils may become so altered that the pH of the surface soil may be as low as 6.0, even though the percentage sodium saturation is more than 15. Laboratory samples should be taken and the following analyses requested: Mechanical, dispersion, total soluble salts, pH (paste and 1:5), percentage exchangeable sodium, and 1:5 salt extracts.

The distribution of alkali in the profile is also important from the standpoint of effect on crops.

Alkali soils, as defined above, will be designated by placing a capital letter "A" in the special factor position.

A - Denotes alkali conditions in general. Use only on preliminary or reconnaissance surveys.

A_1 - Moderate alkali -- alkali conditions such that the growth of most crops is moderately affected. pH (1:5) 8.5 - 9.2.

A_2 - Severe alkali -- alkali conditions such that the growth of crops is seriously affected. pH (1:5) 9.2 - 10.00.

A_3 - Very severe alkali -- alkali conditions such that

the growth of crops is practically prohibited.
pH (1:5), usually more than 10.

The depth to the alkali layers may be shown by overscoring the texture or permeability symbols.

IV. SALINE-ALKALI SOILS

These soils are characterized by: (1) Exchangeable-sodium percentage greater than 15; (2) Conductivity of saturation extract greater than four millimhos/cm.; (3) Under conditions of excess salt, pH is seldom more than 8.5; (4) Salts present are dominantly sodium salts.

As long as excess salts are present, they appear and act like saline soils. As the salt concentration is decreased, they become more like alkali soils. When the soils become strongly alkaline, the colloids disperse and a condition develops which inhibits percolation of water.

These soils will be designated by combining the salinity and alkali symbols, as S_1A_1.

Saline and alkali areas that are too small to delineate and indicate by the above symbols will be shown by the following special symbol: "#" (in red). This symbol will be used in the same manner as the symbols for indicating scattered stones and gravels.

No saline or alkali symbols will be placed in unaffected areas.

When reclamation of an affected area is questionable or will be extremely difficult, overscore the saline and alkali symbols.

V. WATERTABLES WITHIN THE NORMAL ROOT ZONE

Free water within the normal root zone during the growing season often hinders crop growth because it excludes air. This is especially true if there is little movement or fluctuation in the watertable. In most of our irrigated areas, the watertable fluctuates depending upon: (1) Irrigation practices on higher land, (2) River flows, (3) Over-irrigation, and (4) Seasonal variations in water use and supply. Where watertables fluctuate during the year, the evaluation of its effect will have to be based upon the position of the watertable during the major portion of the growing season.

The effects of watertables within the root zone on crop growth are closely associated with the soil profile. Soil conditions favoring rapid water movement, especially by capillarity, are affected more readily than other kinds of soils. Upward movement is slow in

slowly or very slowly permeable soils. It takes a long time for these soils to show harmful conditions. Also, very rapidly permeable soils do not contribute to upward movement of water for any appreciable distance above the watertable. In making field evaluations of the effect of watertable, all of these factors must be considered. As you accumulate important facts about an area, write them into the survey record, and send copies to the state soil scientist.

Whenever the watertable is encountered within 60" of the surface, the depth to it will be recorded on the field map in inches in blue, as 42". The watertable conditions will be evaluated and shown by placing one of the following letters (in red) to the right of the fraction type symbol.

- W - Generally affected by watertable. Use only where no sub-division of conditions required, as in preliminary and reconnaissance surveys.
- W_0 - Beneficial watertable. Watertable occurring under such conditions that the adverse characteristics of moderately or severely droughty soils are significantly decreased. The actual need for the use of this symbol is expected to be limited, and conditions for its use should be described specifically in the survey instructions.
- W_1 - Adapted crops slightly affected, planting dates slightly delayed or the range in kind of crops slightly limited.
- W_2 - Adapted crops moderately affected. The range in kinds of crops is moderately limited. Still suitable for rotations if certain kinds of crops are selected.
- W_3 - Adapted crops seriously affected. Lands best suited for production of water-tolerant irrigated pasture species.
- W_4 - Watertable at or near the surface the major portion of the year. But land can be used for a part of the year for grazing of palatable native species such as sedges.
- W_5 - Permanently wet, swamp areas.

When drainage of an affected area is questionable or extremely difficult, overscore the watertable symbols.

VI. AREAS SUBJECT TO OVERFLOW

- f - Denotes general overflow conditions. For use in preliminary or reconnaissance surveys where no sub-division as to frequency is required.
- f_1 - Susceptible to occasional overflows or overflows

of short duration. Crops occasionally damaged.

f_2 = Susceptible to frequent overflow or to occasional very destructive overflows. Crops frequently damaged or kind of crops severely limited.

f_3 = Very frequent damaging overflows or overflows of very long duration. Not feasible for growing cultivated crops.

Occasional overflows that do no, or practically no, damage should not be designated by the overflow symbol.

VII. DEFICIENT MOISTURE

Those areas where the capability is limited by a deficiency of moisture will be designated by the capital letter "Z" (in red). It is to be used only when no other factor shown in the composite symbol will account for the capability. Iso-hyetal lines in dry farm sections or canals in irrigated lands will often obviate the need for the use of this special symbol.

In dry farm areas where adequate information is available on precipitation and it is the limiting factor in the classification, iso-hyetal lines (to be indicated by bold, dotted lines in red....) may be used to show the approximate boundaries between the significant precipitation zones instead of placing the letter "Z" in each delineated area. If this procedure is followed, all survey tabulations will have to be classified as to the particular rainfall zone in which they occur. The zone must be shown on all field maps, the table showing land use capability by soil groups and CS-1 forms.

In irrigated areas, the site factor symbol "Z" will be used primarily to designate those areas located within the boundaries of the canal system that are too high to be irrigated. It will be necessary also to place the symbol "Z" in each delineated area of the survey above the canal system unless the canal is the survey boundary designating a change in survey intensity. Classification tables will then be developed for each survey intensity. The canal in this case will serve as a boundary between irrigated land and other land uses. If, however, only one classification table is developed, the "Z" must be used.

VIII. SOIL DETERIORATION

The capacity of a soil to produce is frequently modified to a marked degree by certain changes in the soil that cannot be described or evaluated in terms of soil loss. A deterioration of the topsoil associated with a loss in surface mulch and the organic matter of the top layers causes a significant reduction in the biotic activities in non-arable soils. This decrease in biological activity

brings about a consequent reduction in aggregate formation and stability. The surface is subjected to dispersion through impact from raindrops and exposure to high temperatures. The dispersed soil particles then reduce permeability and aeration by clogging the "pores" and forming "seals." In cultivated soils, excessive tillage and tillage at improper moisture content, accelerate this soil deterioration. Even though there is no actual soil loss, the productive capacity of the soil is decreased and treatments are needed to rejuvenate the soil.

On cultivated soils the texture and permeability symbols will be overscored to denote this deterioration. When it is associated with alkali the special factor "A" will be shown, the textural profile will be mapped and the symbols designating the affected layers, will be overscored.

On non-arable lands, the capital letter "M" will be used to denote deterioration. Intensity will be indicated by sub-numerals:

M_1 - Moderate
M_2 - Severe
M_3 - Very severe

IX. POSITION

The letter "T" will be used to designate lands subject to deterioration because of position. Generally the hazards exist but actual conditions limiting present land use have not developed. Areas subject to bank cutting, of potential development of poor drainage, alkali or flooding, are typical of such lands. Sub-letters, consisting of standard special factor symbols, will be used to show different hazards; for example, T_s denotes an area subject to potential development of salinity because of position. These sub-divisions will be defined in the survey instructions.

X. VEGETATIVE OBSTRUCTION

The capital letter "V" will be placed in the special factor position to designate areas where the vegetation is of such type and density that clearing and/or grubbing will be required before the land can be cultivated. This will be used to maintain consistency in present condition classification based on special factors. The land use symbol and vegetative type designation will reflect the type of the vegetation to be removed. If separations are needed to show different intensities, use sub-numerals and define in survey instructions.

LAND CLASS SYMBOLS

Present condition class will be shown by Arabic numerals and land

use capability by Roman numerals; such as $\frac{\text{II}}{4}$. These symbols may be placed on the map in soft pencil at the time of mapping. When irrigated and dry farm lands occur within the same survey area, the classification of the irrigated lands will be shown as $\frac{\text{II}}{4}$, and the classification of the dry farm lands will be shown as $\frac{\text{II}_D}{4}$; Chapter II will treat concepts and principles of land classification.

MISCELLANEOUS

I. DESIGNATION OF CULTURAL FEATURES WITHIN MUNICIPAL BOUNDARIES

It is not essential that the built-up section of municipalities, or the areas covered by commercial developments be inked upon field maps. The Cartographic Division will be able to complete the maps in these areas directly from the aerial photographs. However, it is necessary to show the corporate limits, the main buildings, such as Post Offices, schools, and Churches, and the main highways.

The small townsites of approximately one square mile or less should be designated by complete soil conservation survey symbols. The undeveloped land, as well as farm land within the limits of larger cities, should also be mapped. The boundaries need not be sketched in such detail; just enough to indicate the main features.

It is not necessary to map soil, slope, and erosion in large cities, but whenever the three-part symbols are not used, a definite boundary should be drawn so that the area can be accounted for in the measurements without difficulty.

REFERENCES

1. Conservation Survey Handbook, U.S.D.A. Misc. Pub. 352.

2. Guide for Soil Conservation Surveys, SCS, Washington, D. C., May 1, 1948.

3. Saline Soils, Their Nature and Management, Magistad and Christiansen, U.S.D.A. Circ. 707, September, 1944.

4. Diagnosis and Improvement of Saline and Alkali Soils. U.S. Regional Salinity Laboratory Publication, July, 1947.

Plate 1

SYMBOLS FOR USE IN MAPPING*

Special Symbols

Areas of Continuous Bank Cutting

Drain, open

Drain, closed

Structure Threatened by Flood Damage

Structure Damaged by Flood

Erosion in Irrigation Ditch

Gully Head Cut

Flume

Siphon

Headgate

Drop

Turnout

Stocktank, Charco, etc.

Irrigation well

Earth Escarpment

Boundaries

Reservation line
Indian, Military, National Forest, Park or Monument

Roads

Hard-surfaced

* In addition to symbols given in Misc. Pub. 352

APPENDIX A

FIELD CLUES FOR DETERMINING SOIL PERMEABILITY

Insert this material as part of Chapter I, in the copy of the Regional Soil Conservation Survey Handbook that you have. It is the information assembled to date in this Region concerning soil characteristics and associated permeabilities. It is preliminary and tentative. It is not intended to cover all possible conditions but rather to serve as a guide and give the methods used in evaluating permeability. A key is included showing the relationship of soil characteristics to permeability for a few conditions. Because this is a new field, only limited information is available. As more data become available, the material will be revised. This manuscript has been prepared by T. B. Hutchings and C. H. Diebold.

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FIELD CLUES FOR DETERMINING SOIL PERMEABILITY

Frequently, in evaluating soil deficiencies we consider only those factors which are associated with the fertility of the soil -- the levels of phosphorus, potash, nitrates and organic matter. These are essentials, but in order for them to exert their maximum effectiveness on the productivity of the soil it is equally important that a good soil environment be provided and maintained. A good environment requires that soil, air, and water be in balance.

The majority of the soil organisms require oxygen to carry out their life processes. Organic matter is oxidized in the presence of air by the aid of bacteria and fungi. Soluble plant foods result. If the amount of oxygen in the soil is limited, there is competition between micro-organisms and plants. As the air supply diminishes there is a change in the kind of organisms. Anaerobic types develop and take their oxygen out of oxygen-rich compounds like nitrates (NO_3) and sulfates (SO_4^{--}). They leave reduced substances, such as nitrites and sulfites which become poisons to the oxygen-loving life in the soil. Normal aggregate formation is slowed or stopped. The bright, healthy soil colors associated with well-aerated soils change to the dull bluish or gray colors of oxygen-deficient soils.

Changes in the soil microscopic life may take place in relatively short periods, but with large plants the adjustment to changes in environment comes about more slowly. Consequently, the plants growing on the land at the time these adverse conditions develop show harmful effects. Healthy tissue becomes "diseased." The small roots of the plant usually thicken and in the later stages of oxygen shortage, die back from the growing tips and decompose. Productivity decreases. Often a deterioration in soil structure is the cause of, or at least is associated closely with, such changes.

In some soils this lack of oxygen may be caused by too much water in the soil. Water fills the pore spaces and crowds out the air. Once crowded out, it is difficult to bring back. When soils stay wet, good structure breaks down. The cementing materials that bind the soil aggregates are changed and the soils run together, lose their structure and become massive. Even after such soils are drained, it takes deep-rooted crops, drying and time -- to rebuild a stable soil structure.

In well drained soils the air may be crowded out by compaction. The soil "grains" become packed so closely together that the air spaces between them become discontinuous, fewer in number, and

very small. Compact soils have a high relative volume weight when compared with similar soils that are not compacted. Air movement is retarded or stopped. Compact soils have a low air capacity and roots usually do not go where they cannot "breathe."

In some of our soils the entire profile may be compact but more often such conditions are limited to layers within the soil. These may be naturally occurring layers such as clay pans, silt pans or cemented hardpans. On the other hand, they may be caused by plowing or cultivating to uniform depths, especially when the soil is rather moist.

The type of soil structure that may be associated with a tillage pan is shown in Plate 1. Observations to date indicate that when a "slice" of a tillage pan is taken with a spade and examined, it tends to break easiest in a horizontal plane. That is, it shows horizontal breakage. In this example, the horizontal axes of the large structural units are two to four times the vertical axes. You will note both vertical and horizontal breakage in this specimen, but it is dominantly horizontal.

Such structure is not limited to tillage pans. It may develop at or near the surface as shown in Plate 2. There are indications that freezing and thawing in some soils when they are super-saturated, tend to produce a structure with horizontal breakage lines. The plates formed usually overlap the ones just below. The amount of overlap or "shingling" and the relative thickness of these platy aggregates markedly influences the rate of air and water movement. Usually the thinner the plates and the greater the overlap, the slower the rate.

The shape and size of the sand grains and fine gravel in soils may cause them to compact readily. When the soil particles are well graded, particularly those containing angular-shaped sands, the soil may become so compact (dense) that roots fail to penetrate.

In addition, limiting layers may form at the surface if the surface of the soil is not protected by plants, litter, or mulch. The driving effects of rain drops and the explosive action of irrigation water entering hot, dry soil clods, causes these lumps of soil to melt down or slake. Consequently, an unprotected surface soil becomes the source of a tremendous supply of fine, individual soil particles that are readily carried into the conducting channels that lead from the surface. These particles clog the channels and rapidly reduce the intake rates.

Plate 1. Pronounced horizontal breakage in a 11Pl soil. This represents approximately the six to 10-inch depth. Considerable increase in horizontal breakage was attributed to roto-tilling. Some slightly oblique and vertical breakage is evident.

Plate 2. Note that the horizontal breakage of the surface inch is four times that of the vertical. This heavy loam (47% silt) had a saturated permeability rate of .09 inch per hour in late March, soil unit 32H1, Northern Utah SCD.

When the fine particles move into the pore spaces among the stable aggregates the soil becomes more dense and an effective seal is formed. Air and water cannot move freely through these tight layers. The use of silty irrigation water has a similar clogging effect.

Thus we see that soil structure markedly influences the movement of air and water into and within the soil. For years we have observed and mapped soil structure but only recently has there been much progress made in translating the significance of structure (2).

The results of infiltration and permeability studies made in accordance with accepted methods can now be related to the types of soil structure present -- which in turn serve as useful clues in determining plant response.

Presented in these pages are the data collected to date which may serve as a guide within Region 6 for interpreting the various field clues in terms of permeability.

Even though in our work we are interested in the soil properties that influence both infiltration and permeability, the clues presented here are those that have been found to be related primarily to saturated permeabilities. These facts assist in understanding the water relationships of soils for drainage, leaching irrigations, and other irrigations carried out when portions of the soil are saturated. Furthermore, they help in the interpretation of the productive response of a soil as influenced by the adequacy of air movement within it. However, as permeability observations are made, the factors that affect infiltration are noted also and in time it may be possible to point out the most significant; specifically, those that determine intake rates and affect the efficient application of irrigation water.

There is some difference of opinion concerning precise definitions for infiltration and permeability. For our work and purposes we can accept the process of infiltration as the "capability of a mass of soil or sediment to <u>take</u> liquid water <u>into</u> its bulk, across its boundaries from external sources" (3). Our accepted definition of permeability is "the capacity of a soil to <u>transmit</u> air and water" (1). The two processes are related and in some discussions, permeability is interpreted as that part of the infiltration process which takes place after an apparent equilibrium or constant rate of percolation is reached.

Infiltration rates are influenced significantly by several factors. As mentioned above, the condition of the immediate surface exerts a profound influence. When soil aggregates are broken down and the small particles become detached, they filter into and clog the channels which lead from the surface. Anything that prevents soil detachment such as a mulch of plant residues or gravel, or a canopy of vegetation, helps to keep the pores open and the infiltration rates higher.

Infiltration rates are also related to the amount of moisture present in the soil. Normally, the drier the soil the larger and more continuous are the cracks for water to enter. Infiltration is most rapid when the moisture content is low and decreases as the soil approaches saturation. Entry of water into the soil at saturation becomes dependent upon the ability of the soil to transmit water (permeability).

We compare relative permeability rates by measuring the rate of water movement through saturated soil cores under the force of gravity and with a one-inch variable head. This is a slight modification of the Uhland method (4). In using data obtained in this way, one must realize that normally these values represent minimum rates.

In thinking about soil permeability we need to keep one fact in mind -- "water follows the paths of least resistance." Anything that increases the friction or resistance to the movement of water in the soil will decrease permeability. If the "paths" are large and straight (vertical) the water can move rapidly. If they are narrow and winding, the water moves slowly.

For example, when the soil structure is prismatic and the channels are relatively large and vertical, as shown in Figure 1, the water can flow easily. However, as the water enters the individual aggregates, a and b (largely by capillarity), they swell and decrease the effective size of the water path (x). That is one of the reasons why the permeability of a soil approaches a minimum rate as the soil becomes completely saturated. Generally, soils show greatest swelling when

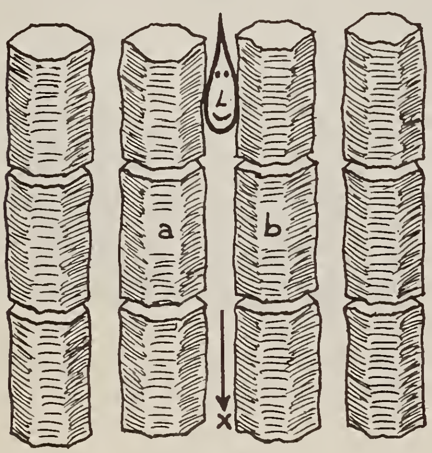

Figure 1. Schematic presentation of water movement though a blocky soil structure.

they are completely wetted. Some soils exhibit considerable swelling when moisture contents are increased from "field capacity" to saturation. The amount of swelling is governed largely by the type of clay minerals making up the soil and the kind of ions held by the clay minerals.

Soils containing clays that are dominantly montmorillonite swell most. They can also adsorb the most ions. If sodium saturated, they swell even more.

Soils containing clays that are dominantly kaolinitic do not swell measurably and their exchange capacity is low. Those consisting mostly of minerals of the illite type have intermediate swelling properties but are dominantly like the kaolinitic group.

It is difficult to measure swelling but the effects may be determined indirectly by observing the shrinkage characteristics of the soils. Note the width, depth and pattern of the cracks. Cracks increase the infiltration rate, especially on heavy tight soils with platy or massive structure. Even though cracks help to get water into the soil and sometimes make it possible to apply an irrigation rapidly, do not over-rate them as to their effect on permeability. Generally, the cracks are not very deep nor do they extend laterally. Consequently, the soil between the cracks and below the surface foot is likely to be deficient in oxygen for good root development. Also the line of fracture may vary from one wetting and drying cycle to another and result in damage to plant roots.

Some of our solonetzic and black alkali soils are characterized by a structure in which the dominant natural breakage is vertical. However, the channels are small and the sodium saturated clays swell rapidly, closing off the channels and practically preventing water movement. In effect, this produces a massive condition in which there are very few paths for the water to follow. Permeability of alkali soils appears to be determined primarily by sodium saturation, dispersion and swelling and, secondarily, by apparent structure and texture.

In soils having platy structure the paths are smaller and winding. Consequently, the distance the water has to move is greater and there is more soil surface to wet per unit depth.

The thinner the plates, the greater the distance the water has to travel and, consequently, the slower the permeability. The small streams become divided as they "work" their way along. Figure 2 shows plates with horizontal axes about three or four times the vertical axes and with a 50% overlap. When these soils approach saturation, the paths become relatively ineffective because of swelling and entrapped air. Such soils are very slowly or slowly permeable unless the effect of the platy structure and horizontal cleavage is offset by oblique or vertical breakage and pores. Do not overlook the effect of pores because they often outweigh the effects of adverse structural conditions. Medium to large (non-capillary) pores are needed to provide channels big enough for adequate air and water movement for rapidly growing roots. In our permeability studies we have observed that pores less than 1/40 inch in diameter appear to have little effect on soil permeability -- presumably because of the effect of entrapped air. Such pores are called fine pores. Medium pores range from about 1/40 to 1/20 inch in diameter. Those larger than 1/20 inch in diameter are designated large pores. Medium pores are considered to be only 1/5 as effective as large pores in water transmission. If there are more than 50 medium pores or more than 10 large pores per square foot and they are relatively continuous the soil is usually at least moderately permeable. Pores serve as the conducting channels and are formed by roots, the activities of burrowing animals and insects and soil shrinkage.

Figure 2. Schematic presentation of water movement through platy soil structure.

Illustrated in Plate 3 is a fragmental type of structure in which the horizontal axes are three to four times the length of the vertical axes. This relationship contributes to pronounced horizontal breakage and the soil appears to have a plate-like structure. Note how the roots follow the cleavage planes. There were only a very few fine roots actually penetrating the aggregates.

The structure illustrated in Plate 4 is dominantly platy. Note the overlapping or shingle effect, especially at the right.

There are many soil properties that influence the permeability of a soil. A given permeability rate cannot be decided upon the basis

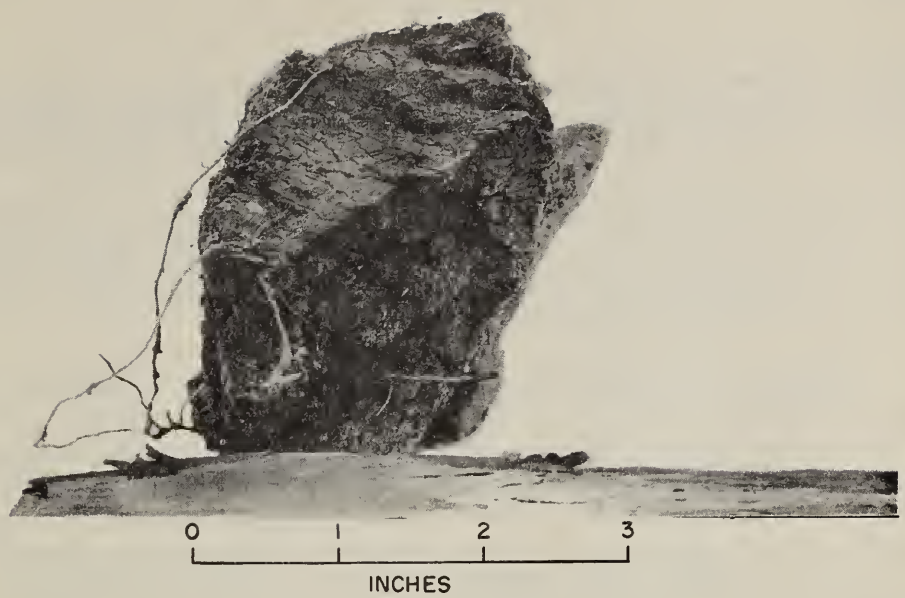

Plate 3. Fragmental structure in the 2 to 6-inch depth of clay soil. The breakage is slightly oblique, but dominantly horizontal. Note how the roots follow the cleavage planes.

Plate 4. Plate-like structure in a clay soil. Note the overlapping at the right.

of the influence of only one soil characteristic. The influences of the various properties are inter-related and the compensating effects of each must be evaluated in making the determination.

Primarily the characteristics to be observed for a specific profile location for the evaluation of permeability are listed below. Form CS-6 suggests a systematic order for making the observations and provides for convenient recording.

1. Texture. Actual mechanical analyses are desirable and when available should be made a part of the record. In absence of mechanical analyses data, estimate the texture and in particular, the percent silt and percent .002 mm. clay. Observations to date in this region show that soils with more than 40% silt tend to have an unstable structure and even though other characteristics suggest moderate permeability, they are frequently slowly or very slowly permeable.

2. Natural Breakage. Take a three-inch or four-inch slice of soil from the side of the pit with a tile spade and determine the direction it breaks with the least pressure. Record whether it is horizontal, oblique, vertical or degrees between these; such as slightly oblique. The breakage may be apparent as the soil lies on the spade, but it is advisable to determine the ease of breakage by hand manipulation. Enough pressure can be applied to fracture any structural aggregates but with care, the direction of natural breakage along cleavage planes may be observed. In soils with massive structure the direction of natural breakage is an important clue to rate of water movement.

3. Structure. There are several characteristics about the structure that need to be noted. These are:

A. Type - Record the type of structure whether platy, prismatic, columnar, fragmental, nuciform, granular, crumb, or massive. Study the national "Guide for Soil Conservation Surveys," May, 1948, particularly pages 23-37, to become familiar with types of structure. Table 1, Page 25, gives size range for each kind of structure. The thickness of the plates in platy structure is especially important. In many of our soils the structure is poorly defined and close examination

is necessary. When the kind of structure cannot be determined readily, make sketches in addition to notes.

B. Stability of structure - This term is used in preference to grade. Stability is perhaps most easily evaluated in the field by the water drop method. Select an aggregate 1/8 to 1/4 inch in size and record number of drops of water required to slake it. Use ordinary dropper bottle and water. Drop from a height of one to two inches. Fine mesh hardware cloth may be used to support the aggregate. If the mesh is too fine the water will not drain freely because of surface tension. Use the following as a guide to relative stability.

Relative Stability	No. of Drops to Slake
Unstable	Less than 10
Moderately stable	10 - 25
Durable	More than 25

Note the condition of the surface. Is it granular, crumb, slick and sealed, or dust mulch? Record such items under notes.

C. Shape of aggregates - Express this by recording the relative and actual lengths of the horizontal axes as compared to the vertical axes; such as H = 2 cm. = 2V -- horizontal axes of aggregates approximately two centimeters long and are twice the length of the vertical axes.

D. Overlap - In some types of structure the aggregates overlap one another somewhat as shingles on a roof. The overlap may be horizontal or oblique. Record the direction and percentage. Overlap is important because it significantly influences the length of the channel through which the water moves. Overlap is difficult to recognize in many soils because the structural patterns are intermingled and poorly defined.

4. Visible Pores. Pores are important because they counteract the retarding effects of a massive condition or a platy structure and heavy textures. Pores less than 1/40 of an inch in diameter seem to be of little value in soil permeability because

of the effects of entrapped air. Pores less than 1/40 inch in diameter are fine pores. Those from 1/40 to 1/20 of an inch in diameter -- about the size of the wire in regular sized paper clip -- are medium pores. Those larger than 1/20 inch in diameter are considered large pores. Give size and number and state whether it is on the basis of a three-inch core, square inch or square foot. Seven times the number per three-inch core is approximately equal to number per square foot. Be sure to note the continuity. Continuous pores conduct water -- others are merely voids.

To evaluate the effect of various sized pores a general relationship has been observed and appears to be best expressed as follows:

$$\text{Effective pores} - \frac{\text{No. of Pores } 1/40\text{-}1/20\text{" dia.}}{5} \text{ plus pores } 1/20\text{" in diameter}$$

5. Density. Record as low, medium or high. If you know the volume weight, record it. The appearance of the surface of a fracture in the soil will give a clue as to its density. Soils of low volume weight ordinarily show a "fuzzy" or "sugary" surface under a hand lens. In moderately compact soils, the grains are less distinct and there is some evidence of a slick or shiny surface. In dense soils, the granules are closely packed and usually have a strong sheen. Sandy textures with the same characteristics have a volume weight of about 0.1 greater because of the increased weight due to higher percentage of sand. A hand lens of seven to ten power is best for field use. Greater magnification is desirable for some observations if a large field can be viewed.

6. Roots. The diameter, depth of penetration, shape and relative abundance by horizons or layers are important clues in determining the adequacy of air and water movement. Relationship of roots to structural units are likewise important. Roots normally do not penetrate dense aggregates.

Old root channels are considered pores.

7. Shrinkage Cracks. It is particularly important to evaluate the beneficial effect these have in balancing the bad effects of very slow permeability. They affect infiltration rates. Record depth and width of cracks and average size of blocks formed between shrinkage cracks. Note also the relative moisture content of the interior of the blocks as compared to the edges.

8. Gravel, Cobble, Stones. Estimate and record the approximate percent by volume. A gravel mulch will affect infiltration rates. On surface samples estimate the percent of surface covered by gravel. When sampling, sample and describe mulch layers separately.

9. Lime. Estimate percentage based upon intensity of effervescence with acid or knowledge of related profiles. Indicate whether disseminated, flecks, coatings or nodular. Dilute one part concentrated hydrochloric acid with ten parts water to make dilute acid for lime tests.

10. Organic Matter. If analyses are available record the percent organic matter. If not, record as low, medium or high for the particular soil unit and climatic environment. The amount of litter on the surface or the percent of bare ground are important clues in determining status of deterioration and water relationships.

11. Colloidal Coating. Normally apparent as a coating on structural aggregates. Record as weak, moderate or strong.

12. Sand Grain Assortment. Note whether they are rounded, flat, or angular, and if they are of uniform size or graded.

13. pH. Colorimetric determination. Place a piece of soil 1/8 inch or less in diameter in a spot plate or on an aluminum foil; add five drops of distilled water and one drop of the appropriate indicator. Compare with standards and record. Readings in excess of 9.0 on soils with textures 1 to 4 are associated with slow or very slow permeability. Values between 8.5 - 9.0 on soils with 1 to 4 textures are usually slowly permeable.

14. Color. The color of different layers and the comparison of color of aggregate surface with interior are useful clues as to the status of oxidation and consequently, the adequacy of aeration. Gray interiors indicate inadequate aeration. If color gives significant clues, additional details should be given in notes. Record color in accordance with standard names used by Soil Survey Division, BPIS & AE.

On the basis of the above characteristics, permeabilities can be estimated with a fair degree of reliability. However, one must remember that the factors that retard water movement may be compensated by those that accelerate water movement. For example, the effects of massive or platy structure in retarding water movement may be offset by low density and medium or large pores. You may

find it helpful to place plus signs on the factors that increase and minus signs on the factors that decrease permeability and then, with judgment, add them algebraically. If the influence of counterbalancing factors is kept in mind, Table 1 may be used as a key for estimating permeability rates on the basis of the above field clues.

To try and illustrate the interdependence of factors we have included some three-dimensional graphs. Such graphs usually relate at least three variables; however, these graphs show four. This is made possible by showing the number of pores by symbols. In studying these graphs, picture in your mind vertical lines rising from a plane surface. The length of each vertical line representing the saturated permeability rate in inches per hour according to the scale at the upper right hand corner of the graphs.

Figure 3 shows graphically the relationship between percent silt, volume weight and saturated permeability. Soils with more than 40% silt are dominantly slowly or very slowly permeable with a tendency toward moderate permeability. As the volume weight increases, the soils become more compact. The silt content may be as low as 30-35%. Those low in silt and high in sand, generally had rapid or very rapid rates. The rates decreased noticeably when the silt percentage exceeded 15.

In Figure 4, volume weight and the direction of natural breakage are shown as they relate to saturated permeability rates. This graph effectively portrays the general effect that relative axis lengths have on permeability and the modifying effects of the number of pores. Some of the soils had massive structure and for these, the measurements represent more the general overall natural breakage rather than the lengths of the axes of the secondary structural units. Because of this, the term "natural breakage" has been used on the graphs and it includes both the axis lengths of individual aggregates and general lengths of natural breakage for soils with massive or single grain structure. When the horizontal axes are longer than the vertical axes and the overlap of aggregates is 25 to 50 the soils are very slowly permeable unless the number of pores offset these retarding influences.

When the vertical axes are equal to or greater than the horizontal axes, there is a pronounced increase in permeability rates. In some cases, swelling offsets the accelerating influence of vertical channels.

In Figure 5, saturated permeability rates are shown in relation to percentage silt and relative natural breakage. The effect of the

TABLE 1.

RELATIONSHIP BETWEEN PERMEABILITY CLASSES
AND DOMINANT CHARACTERISTICS OF NORMAL SOILS

Permeability Class	Texture	Direction of Natural Breakage	STRUCTURE: Type	STRUCTURE: Stability	STRUCTURE: Relation of Horizontal and Vertical Axes	STRUCTURE: Overlap -- Direction And Percent	Number of Effective Pores per Sq. Foot	Density	Remarks
Very Slow Less than .05 inch per hour	Heavy (1)	Horizontal	Massive				0 - 10	Moderate to high 1.3-1.4	Fracture may be vertical but offset by lack of pores and high density.
			Thin Platy	Med. to strong	H > V	25-50% horizontal	0 - 10		
	Mod. Heavy (2)	Horizontal	Weakly developed fragmental	Med. to strong	H > V	25-50% horizontal	0 - 10	High 1.5-1.7	
	Medium	Horizontal	Weakly developed fragmental	Low		25-50% horizontal	0 - 10	Mod. to high 1.4-1.6	
Slowly permeable .05 - .5 inch per hour	Heavy (1) to Mod. Heavy (2)	Slightly oblique	Fragmental	Med. to strong	H > V	0-25% slightly oblique	10 - 20	Mod. 1.2-1.4	
	Mod. heavy	Hor. & vertical about equal	Coarse prismatic breaking to cubical or fragmental	Cubes strong	Equal	Coarse prisms offset slightly 0-25% horizontal	0 - 10	Mod. to high 1.3-1.5	Tend to swell
	Medium (3)	Horizontal	Thin to med. platy	Medium	H > V	Horizontal	0 - 10	Mod. 1.3-1.5	High silt soils with less than 2.5% O.M. may fall here.
		Horizontal	Weakly developed fragmental	Low to medium	H > V	Slightly oblique	0 - 10	High 1.4-1.6	Sand grains flat
Moderately permeable 0.5 to 2.5 inches/hr.	Heavy (1) to Mod.heavy (2)	Oblique	Fragmental	Med. to strong	H > V	Slightly oblique	10 - 20	Mod. 1.3-1.4	
	Mod. heavy	Vertical	Fine prismatic breaking to frag.	Strong	V > H	Prisms 0-25% hor. offset	10 - 20	Mod. to high 1.3-1.5	
	Medium (3)	Oblique	Nuciform	Low	H > V	Oblique	10 - 20	Mod. 1.3-1.4	
	Light (4)	Horizontal	Massive	Low to medium	2H to 3		0 - 10	High 1.5-1.6	Rounded and graded
			Single grain				0 - 10	High 1.5-1.6	
Rapidly permeable 2.5 - 7.5 inches/hr.	Mod. heavy (2) to medium (3)	Vertical and oblique	Nuciform	Med. to strong	Equal or V > H	Oblique	10 - 20	Low 1.2-1.3	
			Fragmental	Med. to strong	Equal or V > H	Oblique	20	Mod. 1.3-1.4	
	Light (4)	Vertical	Single Grain				10 - 20	Mod. 1.4-1.5	
Very rapidly permeable more than 7.5 ins/hr.	Mod. heavy (2) to light (4)	Vertical	Nuciform	Medium	V > H	Oblique	10 - 20	Low to moderate 1.1-1.4	Round, uniform sand grains
	Very light (5)		Single grain				Voids	Low to moderate 1.4-1.5	

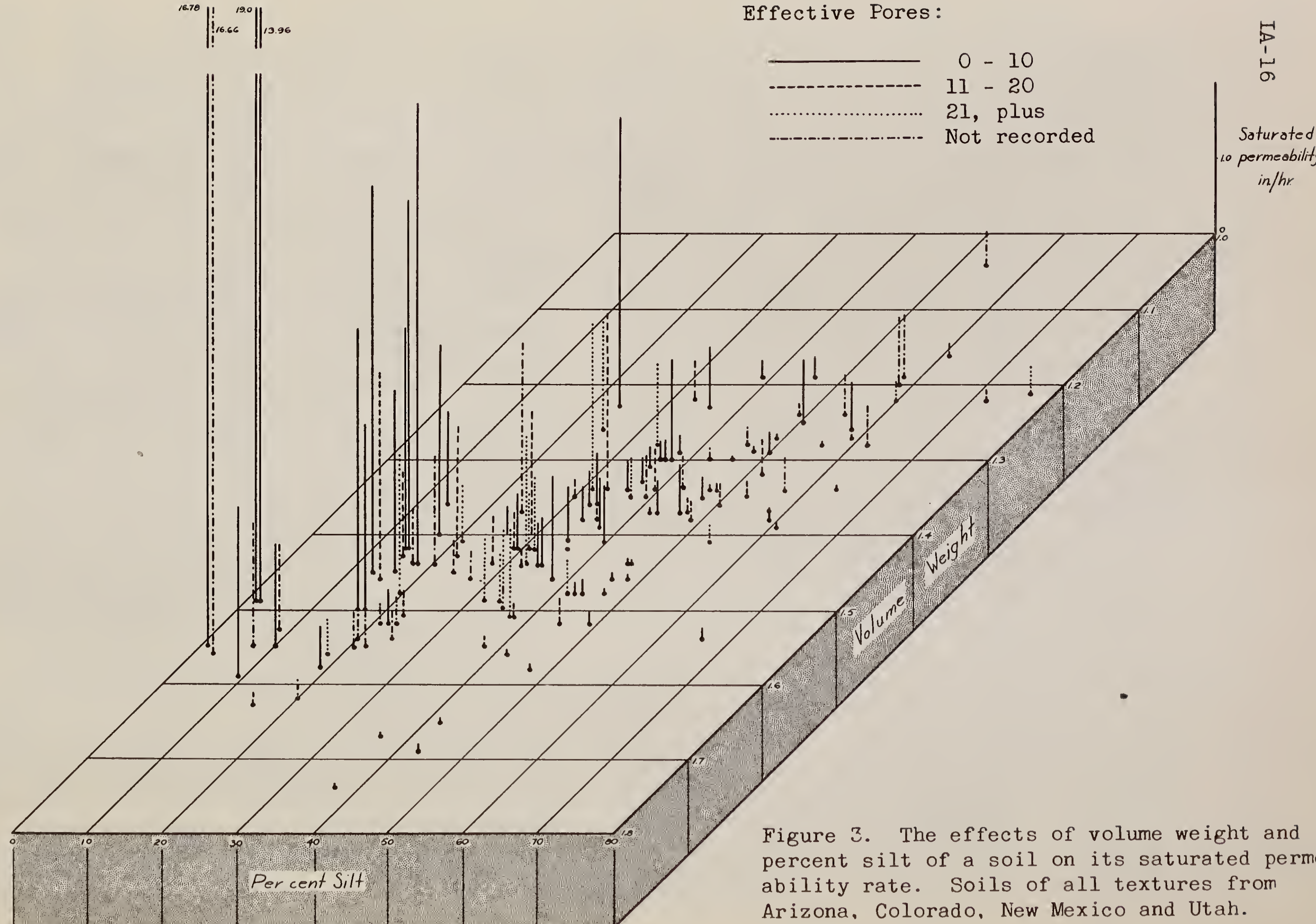

Figure 3. The effects of volume weight and percent silt of a soil on its saturated permeability rate. Soils of all textures from Arizona, Colorado, New Mexico and Utah.

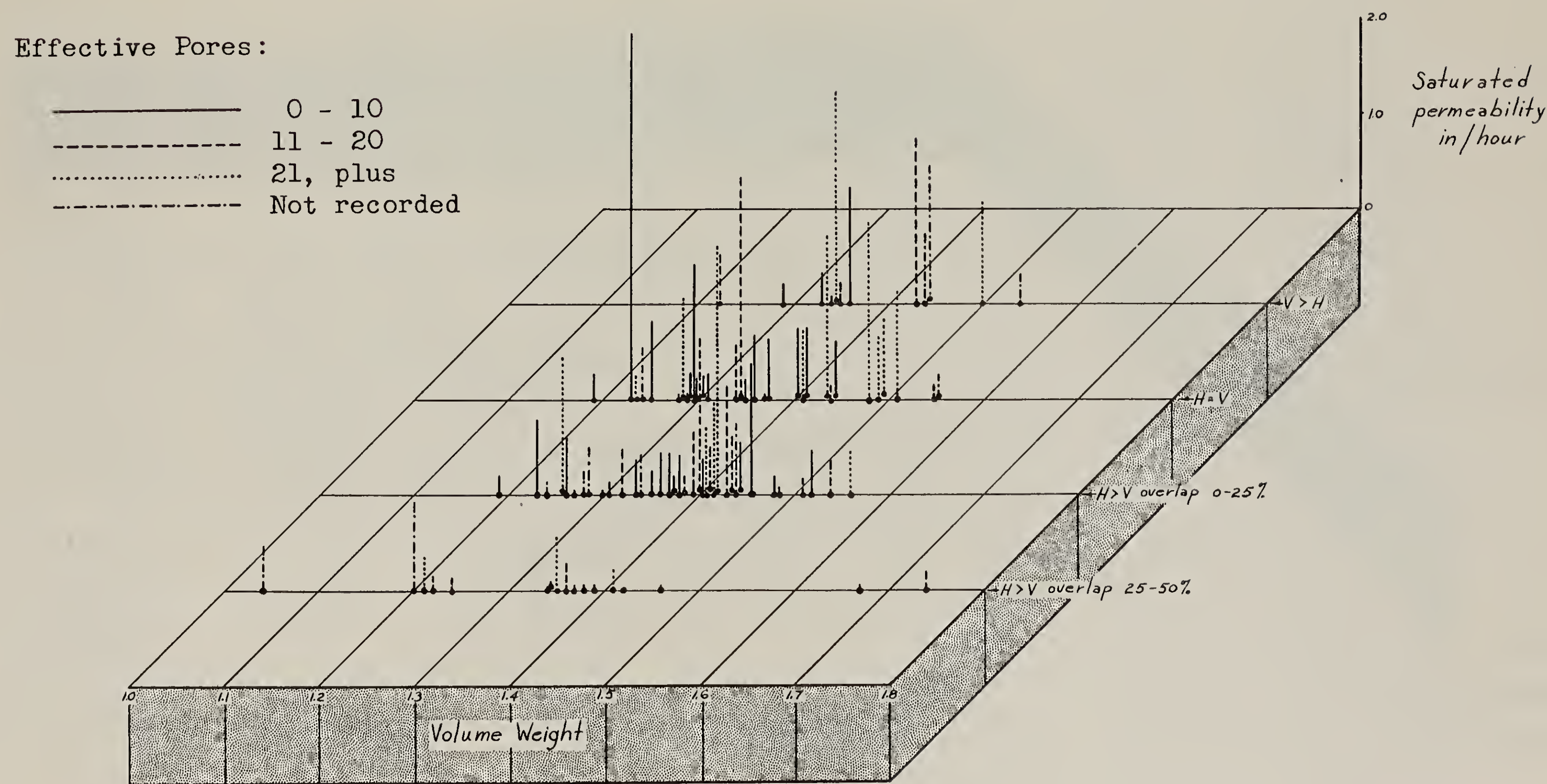

Figure 4. The effect of natural breakage and volume weight on the saturated permeability rates of soils. (H = horizontal; V = vertical) Soils of medium to heavy texture.

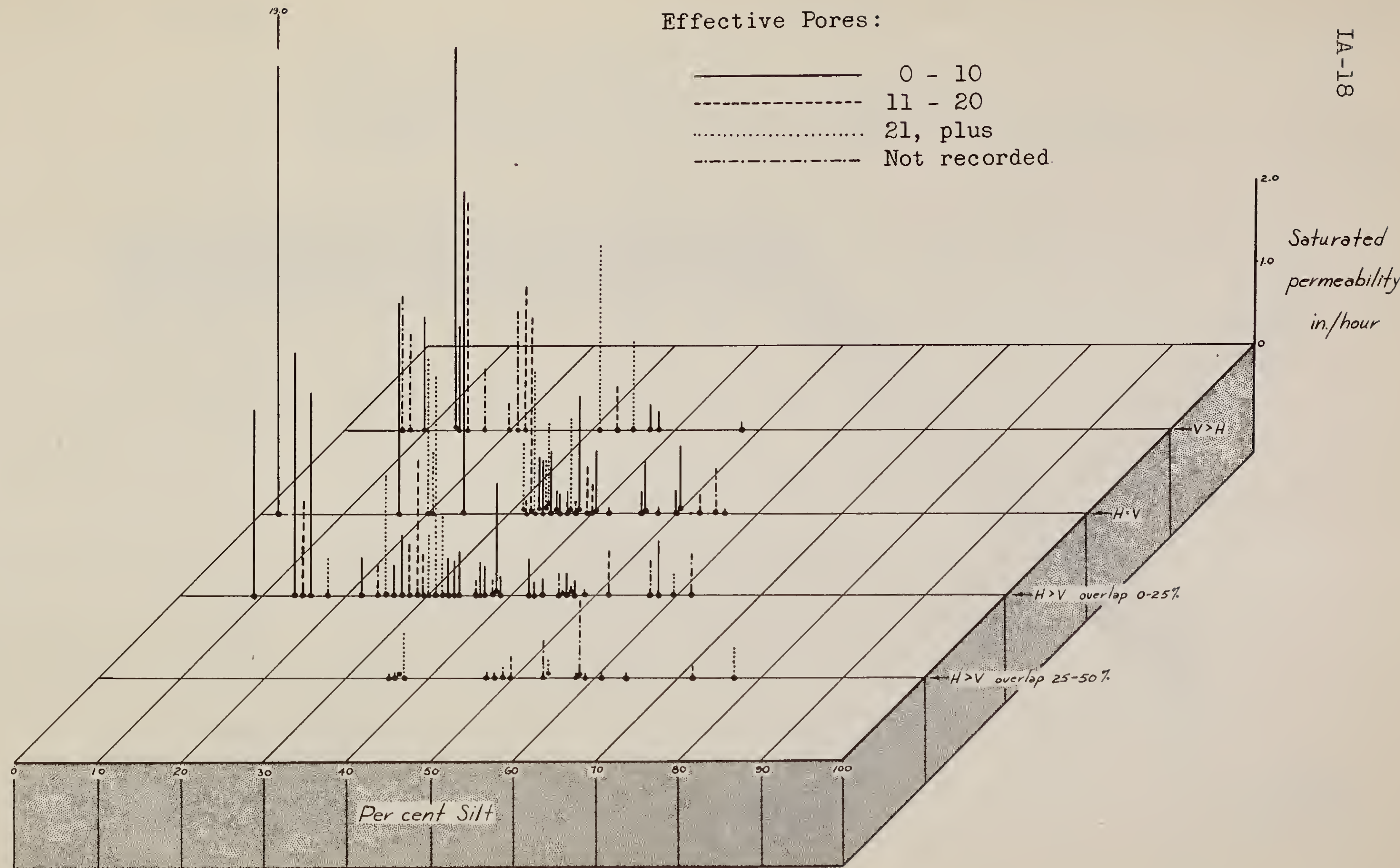

Figure 5. The influence of silt content and direction of natural breakage on the saturated permeability rates of soils. (H = horizontal; V = vertical)

pores on soils containing 25% or more of silt is quite pronounced. Soils low in silt (high in sand) have high permeability rates regardless of pores. In many of these sandy soils it was difficult to assign definite axis lengths because the structure was poorly defined or represented by blocky lumps breaking out of a massive or structureless soil.

In determining permeability, the direction of natural breakage, the kind of structure, relative length of axes, and texture are the primary factors but these must be considered in relation to the other characteristics.

In addition to studying and recording the specific soil characteristics at a particular site, it is beneficial to have supplementary data pertaining to the environment under which the soil has formed. Facts about its origin, parent material, stage of development, distribution and climate are frequently helpful in the interpretation of land needs and capability. The back of form CS-6 provides space for recording some of these items. Make certain that all factors are considered. If it is not pertinent, place a dash in the space to indicate it was considered. Give complete information on location including the soil conservation problem area unit number.

Origin and kind of parent material -- Record whether the soil is residual or transported. If transported, note its position such as foot slopes, flood plains, swales, lake terraces, etc., also whether the sediments are coarse or fine. Flood plains are usually associated with a connected drainage system consisting of permanent or "3 dot streams"; whereas, swales are associated with "1 dot streams" and are not always connected.

Under kind of parent material, include the kind of geologic material or formation from which the soil materials were originally derived. The distribution of zonal soils in arid regions is significantly influenced by the nature of the parent and/or geologic materials. In our work this information becomes particularly significant; for example, as it relates saline formations to salty, dispersed soils. It may give some clues as to relative stability of some of the soils.

Elevation, annual precipitation and storm intensity and duration -- Give approximate elevation in feet above sea level; annual precipitation in inches with a statement as to general distribution. Information on storm intensities and duration assist in evaluating

soil losses. These factors also assist in determining an index for effective moisture.

Stage of Development -- This is important as it influences water relationships within the soil. We are particularly interested in whether or not impeding layers such as silt pans, clay pans, hardpans, etc., have formed as a result of natural weathering processes. Such barriers usually decrease the effective soil depth or impair the water relationships of the soil.

Depth of Solum -- This is considered usually as the A and B horizons and represents the zone of weathering. In many places it may serve as a measure of the effect of climate on the soil. Where rainfall is low it may be difficult to determine this depth. If so, it probably has little significance for our use.

Land use -- If cultivated, give the kind and condition of crops. If in native vegetation give dominant species and relative condition.

Condition of Surface -- The susceptibility of the surface soil to deterioration is a very important factor for all land uses, but especially on those soils under native cover. Very often the condition of the surface is the key to the productivity of the soil because it determines largely whether or not the moisture that falls will become available to plants or be lost as run-off. The surface may be protected by a living vegetative canopy, litter, gravel and stones. Litter may be estimated in pounds per acre; grams per 37-inch quadrat are equivalent to pounds per acre. The effect of gravel and stones can be evaluated relatively by giving the percent of actual surface covered; or the reciprocal of this, the percent of bare ground. Record whether the surface is loose and fluffy or hard and slick. Evaluate dispersion with special consideration to its effect on amount of clogging materials that may be carried in to vertical conducting channels. Note whether the surface is wettable or is water repellent.

Slope -- Give percent, length and general appearance whether smooth, undulating, rolling, etc. Give dominant exposures or in notes give the soil variations associated with exposure.

Erosion -- Indicate whether sheet, wind or gully erosion dominates. Evaluate general activity and extent or percent of areas actually damaged. Where possible, give gully dimensions as an aid in determining severity of problem.

Special Factors -- These are the same as described in Chapter I. Give as much interpretative information as possible particularly as related

to the intensity and permanency of the limitations; the practices needed to condition the land; general desirability and feasibility of doing so.

REFERENCES

1. Guide for Soil Conservation Surveys, Soil Conservation Service, Washington, D. C. May, 1948.

2. O'Neal, Alfred M., Soil Characteristics Significant in Evaluating Permeability. Soil Science 67:403-409. 1949.

3. Smith, W. O. Pedological Relations of Infiltration Phenomena. Trans. Amer. Geophys. Union. 30:555-561. 1949.

4. Uhland, R. E. Soil Permeability, SCS mimeographed release. March 8, 1949.

Form CS-6

UNITED STATES DEPARTMENT OF AGRICULTURE
Soil Conservation Service
Southwest Region

SOIL UNIT DESCRIPTION

Soil Unit__________ SCD____________________ Date__________

Sample No.					
Depth					
Texture					
Natural Breakage (direction)					
STRUCTURE	Type				
	Stability				
	Hor. & Vert. Axes				
	Overlap (Dir. & %)				
Conducting Pores					
Density (Vol.Wt.)					
Roots					
Shrinkage Cracks					
Gravel					
Cobble-Stones					
Lime	(Percent				
	(Form				
Organic Matter					
Colloidal Stain					
Sand Grain Assortment					
pH	(Color.				
	(Elect.				
Color					
Permeability Class					
Saturated Rate					
Field Moist. Rate					
Intake Rate					

SUPPLEMENTAL DATA

Map No.__________ Sec.__________ Township____________________ Range____________________

Drainage Area__________ County__________________________ State________________________

SCPA Unit__________________ Type of Survey____

ORIGIN AND KIND OF PARENT MATERIAL ____

ELEVATION: ____________________ ANNUAL PRECIPITATION __________________________________

STORM INTENSITIES AND DURATION ____
FROST FREE PERIOD ____
STAGE OF DEVELOPMENT__________________________ AVERAGE DEPTH SOLUM ____________________

LAND USE -- Crop or dominant vegetation and condition ________________________________

CONDITION OF SOIL -- Residues, dispersion, infiltration, etc. ________________________

SLOPE -- Percent_____Average length__________Exposure__________: Smooth ( ); Undulating ( ); Rolling ( ); Steep ( ); Precipitous ( ).

EROSION -- Water ( ); Wind ( ); Gully ( ). Frequency and estimated average size of gullies ____

Present activity and extent ____

SPECIAL FACTORS -- ____

CAPABILITY -- ____

NOTES -- ____

THE SURVEY RECORD

CHAPTER 4
SOIL CONSERVATION SURVEY HANDBOOK

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
SOUTHWEST REGION

Guide for Preparing

SURVEY RECORD

The survey record is a progressive, systematic recording of facts concerning the soil conservation survey of a given geographic area such as a soil conservation district or a county. It contains legends, land capability tables, soil unit descriptions, laboratory analyses, climatic data and other pertinent information about the survey. Whoever makes the conservation surveys is responsible for maintaining this record. A large, looseleaf notebook is a convenient binder for the record.

The following outline briefly describes the information to be included in the survey record. A copy of all items in the survey record is to be furnished the state soil scientist or survey supervisor, whoever is responsible for immediate technical supervision in the zone. He will keep a duplicate survey record. When the survey is completed the duplicate copy will be filed by the state soil scientist.

I. TABLE OF CONTENTS AND INDEX

Divide the file into sections as given below and tab each for ready reference.

II. SURVEY WORK PLAN

One copy of the survey work plan for all surveys initiated prior to 1947.

III. FIELD MAP INDEX

On a small scale map show the number and relative position of each photo. If this is not practicable, insert a statement giving actual file location of aerial index map. Where aerial photos are not used, make a sketch map showing the relative position and number of each field map.

IV. SURVEY PROGRESS MAP

Use a standard district outline map or other map of suitable scale to show survey progress. This map is to be kept current and submitted to the state soil scientist upon request. If the map is bulky it may be kept in the map file and a reference sheet giving the location of the map, placed in the record. The field map index and the survey progress may be kept on the same map.

V. SURVEY INSTRUCTIONS, LEGENDS, AND INSPECTION REPORTS

One copy of the original survey instructions and legends, all subsequent amendments and revisions, and related correspondence are to be filed in the survey record. This includes a complete legend of all symbols used on the field sheets with their definitions and limits. File a copy of all inspection reports in this section.

VI. SOIL UNIT DESCRIPTIONS

A soil unit description, form R6-206, is to be completed for a typical soil in each land capability unit. Below the soil unit number on the form, record the national code symbol. This is to be a comprehensive symbol, not abbreviated as would be done for field map use. Under "Notes" on this form, record the significant variations that occur within the capability unit. Narrative descriptions may be written instead of using form R6-206 but they should include all of the information required on the form except actual rate measurements. If narrative descriptions of additional mapping units within a given capability unit are needed, they may be brief, covering mainly the variations between units.

VII. LABORATORY DATA -- SOILS

Salinity, alkalinity, permeability, fertility, texture. For these samples, file copies of "Collector's Description of Soil Samples," form R6-210, in chronological order of field sample numbers in the survey record. These forms are to be filled out completely to provide maximum information concerning land conditions and practices.

When the analytical reports, form R6-205, are received from the laboratory, staple them to the appropriate R6-210 and file in the survey record. In addition, the analytical data may be arranged chronologically by soil unit numbers; or summaries of the data prepared for the soils in each land capability unit. This makes it easier to establish significant ranges and limits for the different properties. Such summaries should be placed in this section of the survey record.

Determinations made at Field Offices. All salt, pH and other determinations made at field offices are to be recorded on form R6-205 and filed in the survey record. A bound notebook may be used as a work book to record bridge readings, etc. (Central Supply number 53-B-22250). The following form headings are suggested: Date, cooperator, photo number, section, township, range, sample number, depth, soil unit, special factor, pH, bridge reading (paste or 1:2), per cent total soluble salt, and initials of analyst. Use abbreviations for column headings.

Earthen Structure Sample Data. The observational and analytical data for such structures will usually be filed in the work unit job files. Such factors as gypsum bearing soils, salty soils, and silty soils, present special construction hazards. A summary statement concerning their approximate location and extent in the district or survey area shall be placed in this section with cross reference to the job file for specific details. A list of the investigations made and their location is to be placed in the survey record.

Drainage Investigations. The observational and analytical data gathered for drainage investigations will be found in the work unit individual job files. A summary statement concerning the complexity and hazards of the problems and their extent should be placed in the record, together with a list of the investigations made to date.

Other Special Investigations. Reports concerning other pertinent investigations are to be filed in this section, i.e., permeability studies, irrigation trials, fertility studies.

VIII. ANALYTICAL DATA -- WATER

Water Quality -- Ion Analyses. File copies of "Collector's Description of Water Samples," form R6-208, in chronological order of field sample numbers in this section of the survey record. These forms are to be completely filled out to provide maximum information concerning the water supply and possible use.

When the analytical reports, form R6-209, are received from the laboratory, staple them to the appropriate R6-208 forms and file in the survey record.

In those districts where irrigation water is obtained from wells, include a small scale map showing the location of the wells and sample numbers.

Analyses Made at Field Offices. Conductivity and other determinations made at field offices are to be recorded on form R6-209 and filed in the survey record. A bound notebook may be used as a work book using the following column headings: Date, cooperator, location (section, township and range), source, sample number, proposed use, pH, bridge reading, class (on basis of total soluble salt), initials of analyst.

IX. LAND CLASSIFICATION

One copy of the Land Classification Table (table 1) and the Table of Recommended Practices (table 2), or their equivalents, are to be filed in the record. Subsequent revisions or amendments to these tables must also be included. Such tables and amendments

must be dated. The tables should show clearly the range of each factor permitted within each capability unit. A complete description of each land capability unit is to be filed in the survey record. Where land capability unit guide sheets have been prepared, copies are to be filed in the survey record.

X. FIELD NOTES

The purpose of field notes is to bring to the attention of the planner, facts pertaining to the land which are not shown or readily apparent from the map. Any unusual or distinctive features such as tillage pans, critical erosion problems, crop history, results of new crops or cropping practices, and unstable soils are some of the items that might be significant.

A card index file is a convenient method for keeping notes. The file can be set up according to land capability unit, soil group, soil unit, or field map. The surveyor can carry a supply of cards, record the important facts, and then file the cards when he returns to the office. Field notes may be kept in a field notebook, summarized at intervals and the summaries placed in the survey record. Do not tear pages from notebooks and insert in record. Copies of field notes need not be supplied the survey supervisor or state soil scientist unless requested.

XI. MAP MEASUREMENT AND COMPILATION

Measure each field map as completed or as each farm is surveyed and record the data on form R6-201 Then submit the R6-201 forms to the Map Measurement and Compilation Section, Conservation Surveys Division, Regional Office. There the information will be transferred to punch cards and summarized. Make CS-1 forms in duplicate. Retain copies in a separate file with cross reference in the survey record.

Summaries will be made in the compilation section for each district or area as requested, and copies supplied for the survey record, district, and state soil scientist's files. One copy of the summaries is to be included in the survey record.

All R6-201 forms must be completely filled out as measurements are made. Whenever there is a change in any one of the factors in the form heading, separate forms for each must be made out. For details, see chapter entitled "Map Measurement and Compilation."

XII. SOIL CONSERVATION PROBLEM AREA MAP AND DESCRIPTION.

All conservation survey data must be compiled by problem areas; consequently, problem area maps and descriptions must be available for convenient reference. Problem areas are to be delineated

and described by Service personnel in accordance with the instructions given in the Conservation Needs Handbook. One copy of the description of each problem area is to be filed in the survey record together with a cross reference sheet giving location of the problem area map.

XIII. SUPPLEMENTAL INFORMATION

Climate. Prepare tables showing average monthly temperature and precipitation for each weather station in the area or those nearby which may be considered characteristic of the area.

On the basis of these data and with the assistance of the state soil scientist or survey supervisor make a climatic zone map for the soil conservation district or area, using crop moisture index as a reference.

Watershed Maps. A map showing assigned numbers for each important drainage is to be included in the survey record. The numbers for major drainages can be obtained from the state soil scientist.

Geology. Maps, sketches, or notes describing the important geologic formations in the area and their influence on soil formation are to be included in the survey record.

Agriculture. Include, (1) types of farming; (2) important crops; (3) important changes in land use; (4) specific problems of soil deterioration; (5) crop yields and special land needs as related to land capability units; (6) photographs illustrating land capability units.

The survey record brings together the legends, laboratory data, climatic information and other pertinent material which supplement the field maps and make possible the most useful interpretation of them. It is equally important with the actual field survey work. Without these essential items, the survey loses its value when those who make it leave the area. It must be kept currently complete. There is no substitute for the survey record.